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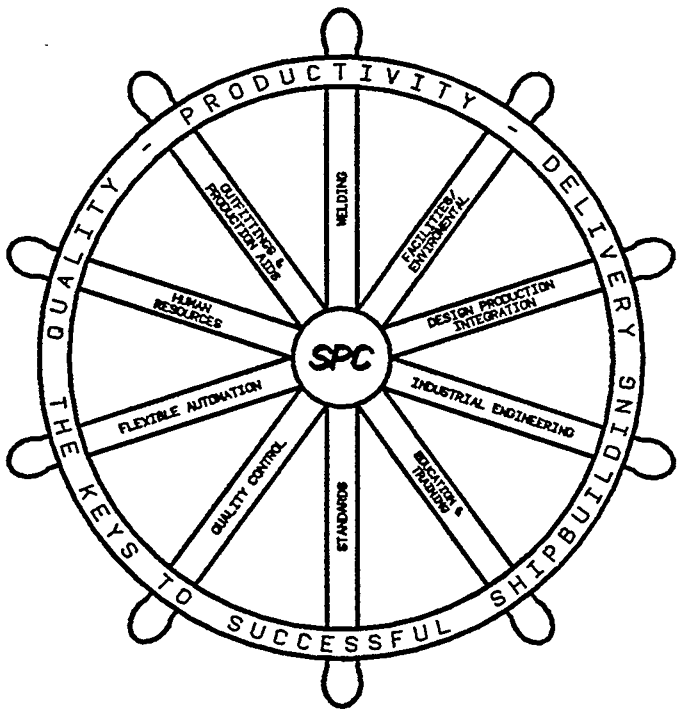

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An Engineering Product Model Based on STEP Protocals

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ABSTRACT

Draft STEP application protocols, developed by the Navy Industry Digital Data Exchange Standards Committee (NIDDESC), have been issued to define the information content of a product model for a ship. The work reported in this paper combines the existing CAD models of the DDG51 Class design with a newly-developed non-graphic database so that the overall information content complies with the STEP protocols. This work represents the first-time implementation of the application protocols and is a significant step in the Navy's plan to do the design of variants of the DDG51 Class totally in CAD. The combined graphic/non-graphic database is referred to as the DDG51 engineering product model. Emphasis has been placed on populating the non-graphic database with the information necessary to perform all required engineering analyses. The basic schema described in this paper may be extended to support other areas of interest, such as logistics support.

BACKGROUND

The U.S.S. Arleigh Burke (DDG51) Class of AEGIS Destroyers represents state-of-the-art technology, and is replacing retiring fleet assets as a vital part of the Navy's smaller, more capable fleet. The design and construction of these warships also feature the application of state-of-the-art technology. As a cost saving initiative and quality improvement measure, the Navy has implemented the use of 3-D Computer Aided Design (CAD). This effort required the development of leading edge CAD technology and the achievement of a cooperative (rather than competitive) success story by the two DDG51 Class shipbuilders and other industry participants.

Over 2,500 drawings, many of which contain over 30 sheets per drawing, are required to build an AEGIS destroyer. Maintaining an error free design baseline defined by these drawings has proven to be a challenge in a 2-D manual environment. To improve efficiency, the entire design is being converted to 3-D CAD. The DDG51 design consists of 77 design zones. A 3-D computer generated representation of each of these zones is being developed. These models contain library parts defining equipment and machinery arrangements, structure, ventilation, electrical, and piping distributive systems.

Library parts are 3-D geometric representations of ship components, and contain maintenance and access clearance requirements as well as attribute information. These parts are constructed once and used many times throughout the ship design. Construction of library parts and zone models is governed by program standards defining content requirements. These are based on actual ship design and construction needs. A CAD model for one of the construction zones for the DDG51 Flight I ships is shown in Figure 1.

Once generated, the 3-D models offer several advantages in enhancing the shipbuilding process. Simultaneous visualization of all disciplines located within a compartment enables concurrent, rather than sequential, system design. With the added feature of dimensional accuracy inherent in CAD geometry, arrangements can be optimized before the first piece of steel is cut. The need to construct costly full scale mock-ups is therefore eliminated. CAD models are also valuable tools for fleet training applications.

For production use, interference and interface problems that were traditionally not detected until actual construction can now be resolved prior to the release of construction documentation to production trades. Interference free/interface correct construction drawings are generated directly from the model. In addition, numerical control data for fabrication of ventilation and pipe is generated directly from the model. For life cycle support, a model representing the as-built configuration delivered to the planning yard will support maintenance and modernization tasks over the ship's forty year life.

To succeed in this effort, the program first had to overcome the incompatibility between CAD systems used by the two different ship construction yards. Sharing data between their ComputerVision

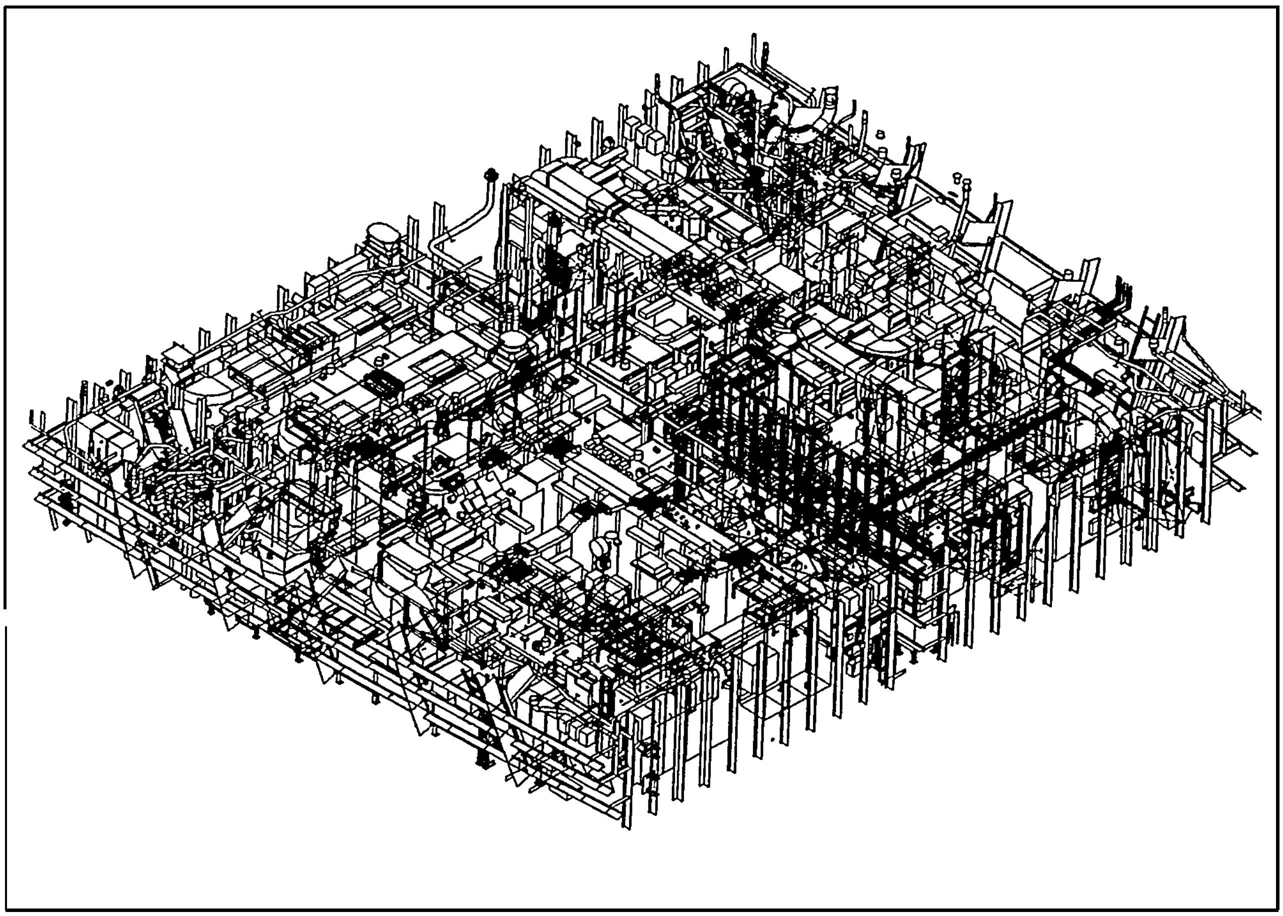

FIGURE 1. DDG51 CAD model.

and Calma systems was not feasible using commercially available software. The Navy elected to develop a translator to exchange ship design information between the yards. This translator required that information exchanged first be processed into a neutral file before receipt by the receiving shipyard. This option provided flexibility for software maintenance, facilitated development of translators to additional CAD systems and most importantly allowed each shipbuilder to continue “business as usual” with the CAD systems already in place at each facility. The use of these software routines is now referred to as the DDG51 Digital Data Transfer (DDT) process (l). In order to formalize and standardize the data transfer process between the shipbuilders, the Navy issued a DDG51 CAD model transfer specification (2), in which the information content of the CAD models was defined.

Development of a standard translator allowed a cost effective transition to 3-D CAD. The task to convert the design to 3-D was shared between the shipbuilders. Data was exchanged via the translators; this eliminated any duplication of effort and also reduced the total time required to convert the design.

One of the most significant uses of the 3-D models will be to support design and construction of the next generation of AEGIS Destroyers, DDG51 Flight IIA. This design features the addition of a helicopter hangar. These ships are to be the first Navy ships designed and engineered totally in CAD. The CAD models will function as electronic baselines to accurately design the modifications. Applying concurrent and human factors engineering will be key factors in attaining the Navy’s goal of reducing the acquisition costs of AEGIS destroyers.

Among the categories of data to be included in the models are geometric-type data (entity coordinates and orientations), connectivity data (where applicable), and some limited object-oriented intelligence. This latter category includes run designations for distributive systems and shipbuilder-defined stock or catalog numbers for individual objects. It is this intelligence category of information which distinguishes the DDT translators from other geometric-entity translators, such as Initial Graphics Exchange Specification (IGES) translators; it formed one of the buiIding blocks for developing an engineering product model (EPM).

During the development of the DDG51 CAD model specification and DDT translators, work was begun on the formal definition of a digital product model for a ship. This work was conducted by NIDDESC, a joint Navy/marine industry effort to draft application protocols (standards) for a breakdown of a ship and its components. The NIDDESC standards will be a part of the STEP (Standard for the Exchange of Product Model Data) international standards. The work of the NIDDESC Committee and a description of the draft standards were presented to the 1992 Ship Production Symposium by Lovdahl, Martin, et al. (3).

The NIDDESC application protocols cover the following technical disciplines: structure, piping, HVAC, electrical and cableways, and outfit/furnishing items. Each discipline’s protocol is intended to cover all phases of a ship’s product model definition, starting with the contract design phase through to detail design and life cycle support of the ships in service.

In addition to defining the information content of a digital product model, each NIDDESC protocol lays out the logical interrelationships between the various types of information or digital data. These interrelationships are defined in terms of information models, called NIAM (Nijssen Information Analysis Method) diagrams.

These diagrams have proven to be of great value in the development of the DDG51 engineering product model since they can be used to establish the architecture of a relational database forming one of the cornerstones of the EPM.

The draft NIDDESC standards are being submitted to the International Standards Organization for approval as part of the STEP international standard. The work reported herein shows the usefulness of the application protocols in their present draft format, and demonstrates a frost-time implementation of the protocols for use in design efforts for the next flight of DDG51 Class ships. The challenge was to put together a working digital product model in a short time frame. The product model not only had to be rigorous in its adherence to the NIDDESC protocols, but also had to integrate the engineering aspects of the overall design process. Engineering processes have not previously been given great emphasis in CAD design work.

Gibbs & Cox, Inc. was tasked by the AEGIS program manager (PMS400D) to use the draft NIDDESC standards and the established DDG51 CAD model content standard as components in the development of an EPM to be used in the design process for DDG51 Flight IIA ships. The purposes of the EPM were to progress well beyond the project's previous goals for CAD; i.e., to integrate engineering analysis functions, and to create a totally digital design process for Flight IIA ships.

PMS400D'S direction was to extend CAD techniques into the early-stage design studies and pre-detail design process for future DDG51 Class upgrade/variant designs. Rather than performing design tasks in a conventional manner, it was decided to capitalize on the immense amount of detail design data available in the various 3-D CAD models already developed. Computer-aided engineering (CAE) applications were to be linked to these detail design databases. PMS400D directed concentration in the area of early-stage engineering. However, it was recognized from the start that the basic product model technology could later be extended to subsequent stages of the ship design and support cycle.

APPROACH

The initial task was to develop a workable product model definition for the DDG51 Class based on the NIDDESC standards, and on the goals set by PMS400D. The product model was defined to consist of two parts: a CAD graphics model developed for the ship construction program for Flight I ships and a non-graphics relational database containing all necessary data not in the graphics models. Initially, the product model developers concentrated on piping systems since that NIDDESC protocol (4) was the most fully developed. Later model development efforts included disciplines such as HVAC, electrical, and outfit/furnishings. The resulting product model was designed to support early-stage DDG51 flight upgrade design development, to be transportable to other organizations (both government and commercial), and to be contractor independent.

One of the first steps in this task was classifying the specified information content in each NIDDESC protocol as graphic or non-graphic data. The detailed approach for this step follows:

A. Each protocol was reviewed in detail to help distinguish between non-graphic elements (i. e, information not immediately available from or derivable from the CAD models), and graphic data.

B. The minimum set of data necessary to conduct engineering/feasibility studies for various types of ship systems was defined. It was intended, for example, that the information content in the combined graphic/non-graphic databases for piping systems would meet the requirements of the following tables in the NIDDESC piping protocol (4):

3.3.1.1 Equipment arrangement
3.3.1.2 Flow analysis
3.3.1.3 Piping system test definition
3.3.1.4 Connectivity check
3.3.1.5 Graphic presentation
3.3.2.1 Interference analysis
3.3.2.2 Connectivity check
3.3.2.3 Bills of material
3.3.2.5 Graphic presentation
3.3.3.2 Pipe installation /assembly definition
3.3.4.1 Support product model cross reference to external product support data/documentation
3.3.5.1 Configuration status and change tracking

c. A relational database was then established to contain all required non-graphic data. Tables for the various types of ship components and systems were created.

D. SQL (Structured Query Language) queries of the relational database were developed to extract all necessary support data.

Examples of graphic information include equipment dimensions, component orientations/locations within the ship, connectivity of components in a system, and piping system sizes (outside diameters). All of these types of data are contained in the DDG51 CAD models, or are easily derivable.

Non-graphic or engineering information selected for storage in the relational database system includes the weight of equipment items, component electric loads and load factors, and piping system component pressure drop coefficients. This information was keyed to the intelligence (stock numbers) in the graphics models. The relational database was designed using a relational database management system (RDMS) running on a RISC computer. It was intended that the combined graphic and non-graphic databases would in essence implement the NIDDESC application protocols' standards for information content.

A schematic representation of the engineering product model is shown in Figure 2. This figure illustrates the principle of combining graphics and non-graphics data to form the overall product model.

The design of the relational database portion of the EPM was guided to a large extent by the NIAM diagrams in the NIDDESC protocols. The diagrams, for example, show the interrelationship between piping system component pressure drop information, specifically, pipe inner diameter and roughness coefficient, and pipe component identification. The inter-relationships are easily converted to the

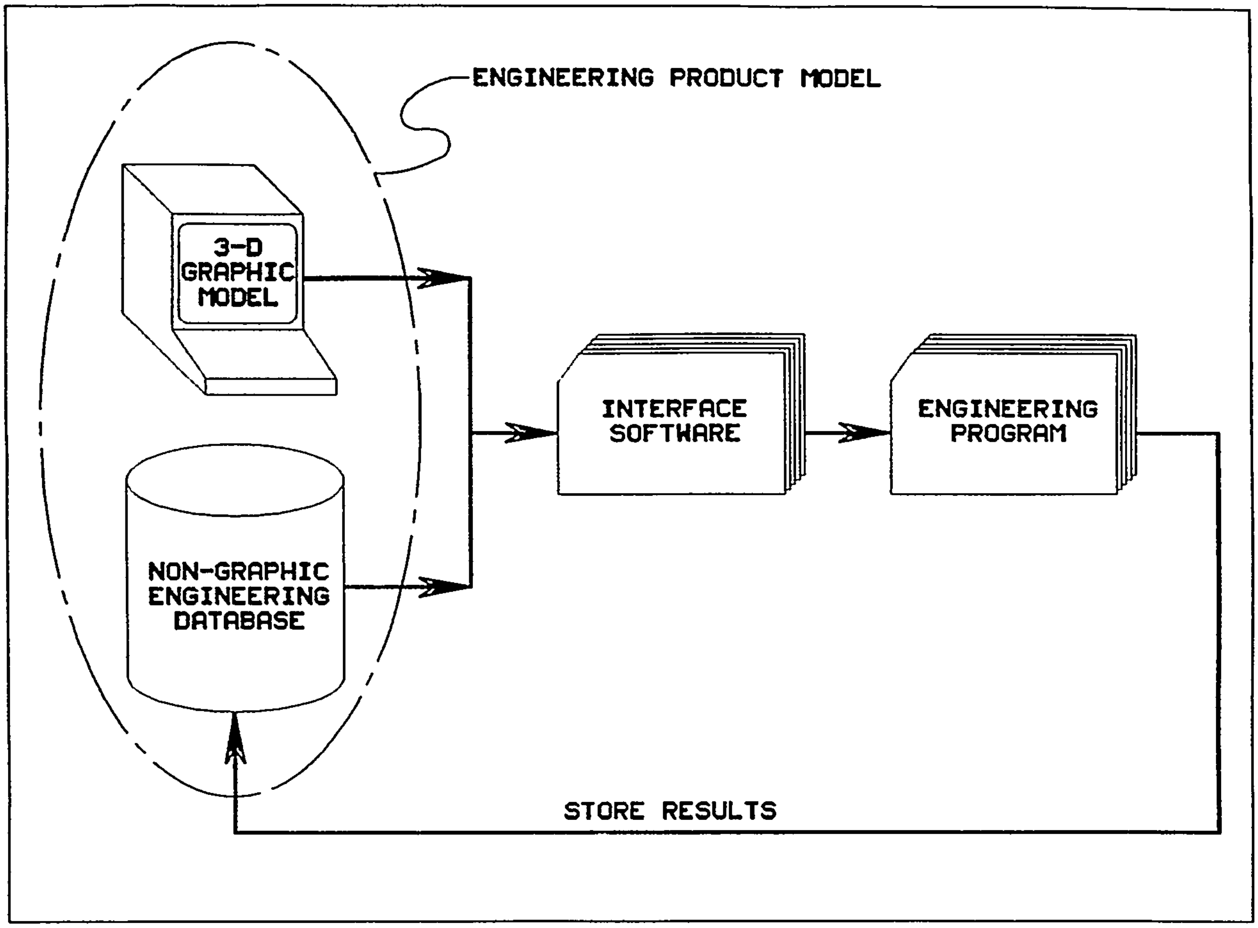

FIGURE 2. Engineering product model schematic.

primary/foreign keys associated with a relational database. Table I shows a portion of a relational database table that relates piping stock number, inner diameter, and relative roughness coefficient.

The process of converting the NIAM diagrams into database tables revealed certain instances in which the diagrams' logic was faulty. These problems were relayed to the authors of the NIDDESC protocols and, in most cases, were corrected in later versions of the protocols.

ENGINEERING PRODUCT MODEL

Once the basic graphic and non-graphic portions of the engineering product model were in place, it was necessary to link them for efficient interaction with each other and with existing engineering analysis software packages. Modern networking capabilities were used to link the graphics workstations to a computer which hosted both the relational database and the engineering analysis programs. Figure 3 illustrates the network established to run the EPM. This novel use of modern networking capabilities makes use of the EPM simple and rapid. It multiplies the computing power available to conventional CAD workstation users and allows true integration of design and engineering functions.

Engineering analysis packages already existed in each technical discipline. All that was required to complete the EPM was to write straightforward interface programs to extract the necessary data from the graphic and non-graphic portions of the EPM, and produce standard input data records for the engineering programs.

The list of disciplines for which interface programs have been written include the following:

- Piping pressure drop
- HVAC pressure drop
- System weights

Spef Pipe Item Spiv	Spef Pipe Item Internal Diam	Spec Pipe Item Rel Roughness
10031-001	0.410	0.000146
10031-010	0.545	0.000110
10031-028	0.710	0.000085
10031-036	0.920	0.000065
10031-044	1.185	0.000051
10031-052	1.530	0.000039
10031-061	1.770	0.000034
10031-079	2.245	0.000027
10031-087	2.745	0.000022

TABLE I. Typical relational database table.

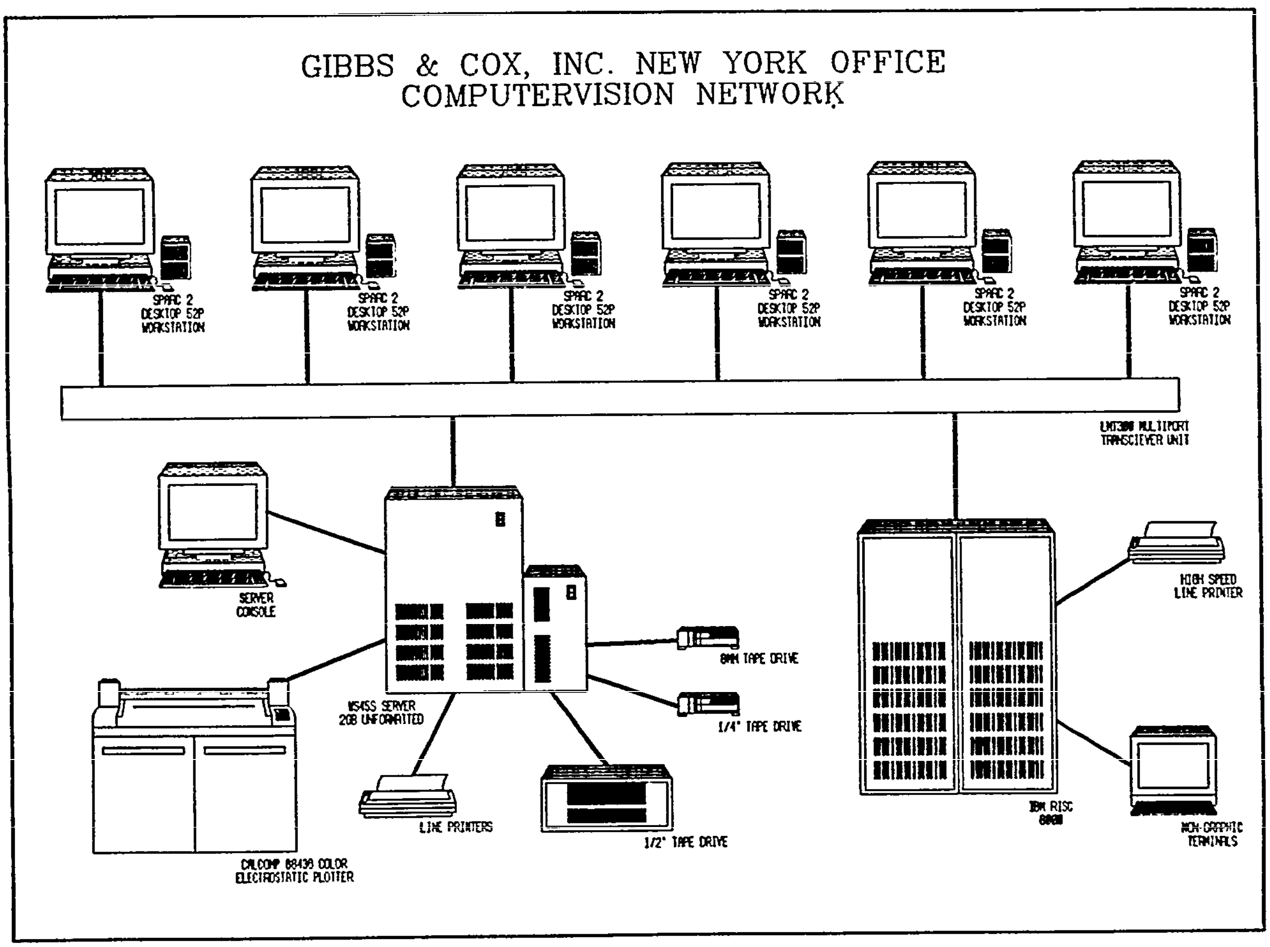

FIGURE 3. EPM computer network.

Electric load analysis
- Heating/cooling load analysis
Foundation design/analysis
Voltage drop calculations, and
Scoping of proposed changes

The traditional approach to performing engineering calculations on shipboard distributive systems has been to have engineers initially size the systems based on assumptions concerning the anticipated system routing. Experienced designers then actually do the detail design routing of the systems and manually check for mutual interferences between systems. After elimination of all known interferences, the distributive system drawings are prepared and issued. The original system engineers take the issued drawings and prepare final calculations based on the system drawing configuration. Often, the final calculations show a need to resize portions of a system and the engineering/design cycle must be repeated.

The traditional ship design and engineering process is a series of operations done over a relatively long period of time. The process also requires the passing of large amounts of information back and forth between various groups in an organization.

The EPM approach, in contrast, can greatly shorten the design/engineering cycles' duration and reduce the man-hour expenditures. Once a CAD graphics model of a distributive system is available---either as a first-cut crude model or as a final detailed model---the engineering product model's relational database and associated engineering programs can be used to do all the required system calculations. Since both the design and engineering groups are using a common CAD database as their basic frame of reference, the problems of communication between groups are vastly simplified.

The engineering product model has another significant effect which was not evident at the outset of the project. The EPM greatly simplifies configuration control of the resulting design and its associated engineering analyses. Because the design/engineering cycle times are shortened, engineering analyses can more easily be kept up to date. Using a common graphic database also means fewer opportunities for omissions or errors in the engineering calculations. Configuration control of the database is not onerous, since most of the information is catalog-related, and therefore changes relatively infrequently.

The EPM methodology can be applied throughout all phases of a ship design project. In the earliest phase, functional design, relatively simple first-cut graphics models can be developed as baselines. For DDG51 Flight IIA, a series of such simplified models have been assembled into a single enhanced geometry control model. For later design phases, detailed zone-level CAD models will replace the first-cut models. In all design phases, the combination of CAD graphics information with the EPM's relational database remains the principle for producing all required engineering calculations.

SUMMARY

The development of the DDG51 engineering product model has demonstrated the basic validity of the draft STEP standards issued by the NIDDESC Committee. Moreover, by subdividing data into classifications of graphic/non-graphic information, the engineering product model has shown one way in which NIDDESC protocols can be implemented in the near-term on existing CAD systems. using existing relational database software and modern networking capabilities makes it feasible to construct a ship product model that conforms to NIDDESC standards now, without awaiting the creation of specific STEP standard software and/or translators.

Joining engineering calculation procedures with CAD graphics models significantly reduces engineering man-hours and shortens overall design/engineering cycles. For example, using the engineering product model methodology on a recent CAD zone model for DDG51 Flight II allowed calculations for an entire sprinkling system to be accomplished in four man-hours, and to be completed within one working day. Comparable calculations done by traditional methods would have required at least forty man-hours and several weeks, allowing time for passing data back and forth between the design and engineering groups. The efficiencies displayed in early testing of the EPM are impressive. The EPM should provide an answer to the Navy's pressing need in today's environment to reduce design costs for ships.

One final benefit of the engineering product model approach is a vastly simplified configuration control. Since both design and engineering groups use a common graphics baseline for their work, they will face fewer problems in the transfer of information between groups. The chances for error are obviously reduced, and the overall cycle time for every phase of the ship design process is shortened.

REFERENCES:

1. Joanne J. Ouillette, "DDG51 Class Computer Aided Design," ASNE DDG51 Symposium, September 1992,
2. "DDG51 Class Lead Yard Services Digital Data Transfer Project Functional Specification, Revision C (phase II)," March 1990.
3. Richard H. Lovdahl, Jr., Douglas J. Martin, et. al., "The NIDDESC Ship Product Model: The STEP Solution," SNAME 1992 Ship Production Symposium, September 1992,
4. Douglas J. Martin, "NIDDESC Piping Application Protocol, Version ().7, " March 1992.

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